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THRESHOLD CERENKOV COUNTERS IN SECONDARY BEAMS AT NAL

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Introduction

We propose the use of the vacuum pipe in the secondary beams for a threshold Cerenkov counter(s). These secondary beams will be 100 m to 300 m long and will be more-or-less ideal for use in a non-focusing threshold-type Cerenkov counter. The small pressures of gas that will be required will produce little multiple scattering and hence will not degrade the emittance of the beam; the number of interactions in the gas is also small.

As an example of a secondary beam, consider the beam designed by Petrucci et al.[1] It is 180 m long, accepts 10 μster, has a $\Delta p/p$ of 3% and operates up to 300 GeV/c. (See Figs. 1 and 2.) The expected ratios of particles at the end of the beam are given in Table I. For this example, the light could be collected at three separate stations, the last being just ahead of the experiment. The electronic pulses could be added to achieve an effective length almost the length of the entire secondary beam: the pulses could also be put in coincidence or the sections of the pipe could be operated at different gas pressures, and three separate threshold Cerenkov counters could be achieved each with a different threshold. The operation of the Cerenkov counter places no restriction on the design of the beam other than the use of a shiny pipe.

Counter Design

The Cerenkov light from the beam particles is near 0° angle. The useful length for producing and collecting this light extends between bending magnets. The need of a good reflector for the large angles encountered in the bending magnet is unnecessary; one merely collects the light ahead of each such bend. A 45° mirror (perhaps 1/2 mil aluminized mylar in the secondary beam ahead of the bending magnet) could reflect the light out of the beam to a quartz window photomultiplier tube located inside the beam pipe vacuum system to eliminate the need of an extra window.

On the average the Cerenkov light will undergo a couple of reflections in 50 m beam pipe. Therefore, a requirement on the beam transport is that the vacuum pipe be a good reflector of light at very small angles. This might be accomplished by lining the pipe with a glass tube, either aluminized or not, or by coating the inside of the tube with epoxy and spinning it as it cures in order to get a smooth circular cross section which then might be aluminized.

The phototubes should have a photocathode diameter to match the diameter of the beam pipe, have high photocathode efficiency and have a quartz window.

We considered three gases as possible Cerenkov radiators: hydrogen, nitrogen, and helium. Comparing the number of photons/cm emitted in the region 3500 Å -5000 Å by particles with $\beta = 1$ at NTP (H_2 = 0.11 photon/cm; N_2 = 0.23 photons/cm; He = 0.027 photons/cm we find that helium is a poor Cerenkov radiator. Figure 3 is a graph of $1-\beta$ for p, K, π, and μ from 10 to 300 GeV/c. The threshold pressure in atmospheres is also indicated for hydrogen and nitrogen gases.

Hydrogen gas is preferred from the standpoint of having the least multiple scattering and the fewest interactions. For example, in a 50 m long counter at the K threshold at 50 GeV/c, hydrogen would give 6×10^{-6} interactions and 3×10^{-6} radiation lengths while nitrogen gas would give 16×10^{-6} interactions and 27×10^{-6} radiation lengths. The safety problem with hydrogen is minimized by proper design of the end window; the total amount of hydrogen is not large because of the low gas pressures involved. For hydrogen gas at STP, 50 m long pipe 4 in. in diameter, the liquid equivalent is 1.6 liters of liquid hydrogen (112 g).

Calculations of detecting delta rays for particles which would not otherwise be counted are summarized in Table II. It is evident that the background from delta rays is small, a conclusion in agreement with detailed calculations of R. Ely.[2]

Conclusions

It appears that the incorporation of threshold Cerenkov counters in the vacuum pipe of charged secondary beams is practical at NAL.

The additional expense is very moderate, the restrictions in the design of the beam are absent. Integrating the light output could, in addition, be a very good way to make precision absolute beam monitors sensitive to certain mass particles.

REFERENCES

[1] Petrucci et al., CERN/EDEA 67/16 Vol. II, p. 19.

[2] R. Ely, Lawrence Radiation Laboratory UCRL-16830, April 1966, p. 170.

Table I. Particle Ratios at the Experiment.

P(GeV/c)	$P/\pi^+/K^+$		$\pi^-/\bar{P}/K^-$		π^+/π^-	
	2 mrad	≤ 8 mrad	2 mrad	≤ 8 mrad	2 mrad	8 mrad
50	1.2/15/1	0.75/10/1	$100/6\times10^{-2}/1$	$100/1.5\times10^{-1}/1$	2	2
100	5/13/1	5/1/1	$200/5\times10^{-3}/1$	$110/10^{-1}/1$	4	4
150	9/8/1	16/7/1	1000/-/1	450/-/1	5	6
200	90/8/1	70/12/1	7000/-/1		8	

Table II. Probabilities for Detecting Delta Rays (50 Quanta) From Kaons, for Counter Section 50 m Long.

A. H_2 gas

P(GeV/c)	$\theta\delta$ mrad	ℓ(m)	E'_δ(GeV)	σ(E, E')mb	$Prob_\delta$
50	10	10	3	8.0×10^{-2}	10^{-5}
100	3	36	10	2.5×10^{-2}	10^{-6}
150	1	100	35	7.0×10^{-3}	10^{-7}
200	0.5	180	50	5.0×10^{-4}	3×10^{-8}

B. N_2 gas

50	12	8.4	2	1.2×10^{-1}	4×10^{-6}
100	3.5	28	10	2.5×10^{-2}	2×10^{-7}
150	2.5	42	35	7.0×10^{-3}	4×10^{-8}
200	2	55	35	7.0×10^{-3}	3×10^{-8}

P(GeV/c) = kaon momentum

θ_δ(mrad) = maximum angle for detected δ rays

ℓ_δ(m) = length of δ-ray track to count

E'_δ(GeV) = minimum δ-ray energies that count

σ(E, E') mb = internal cross section for δ rays with energies greater than E'

$Prob_\delta$ = probability of detecting a δ ray in a counter section of 50 m long

FIGURE CAPTIONS

Fig. 1. Petrucci beam showing the three sections C_I, C_{II}, and C_{III} that can be used for Cerenkov detection.

Fig. 2. Optics of the Petrucci beam.

Fig. 3. The quantity $(1 - \beta)$ and the threshold pressure for hydrogen and nitrogen Cerenkov counters as a function of momentum for various particles.

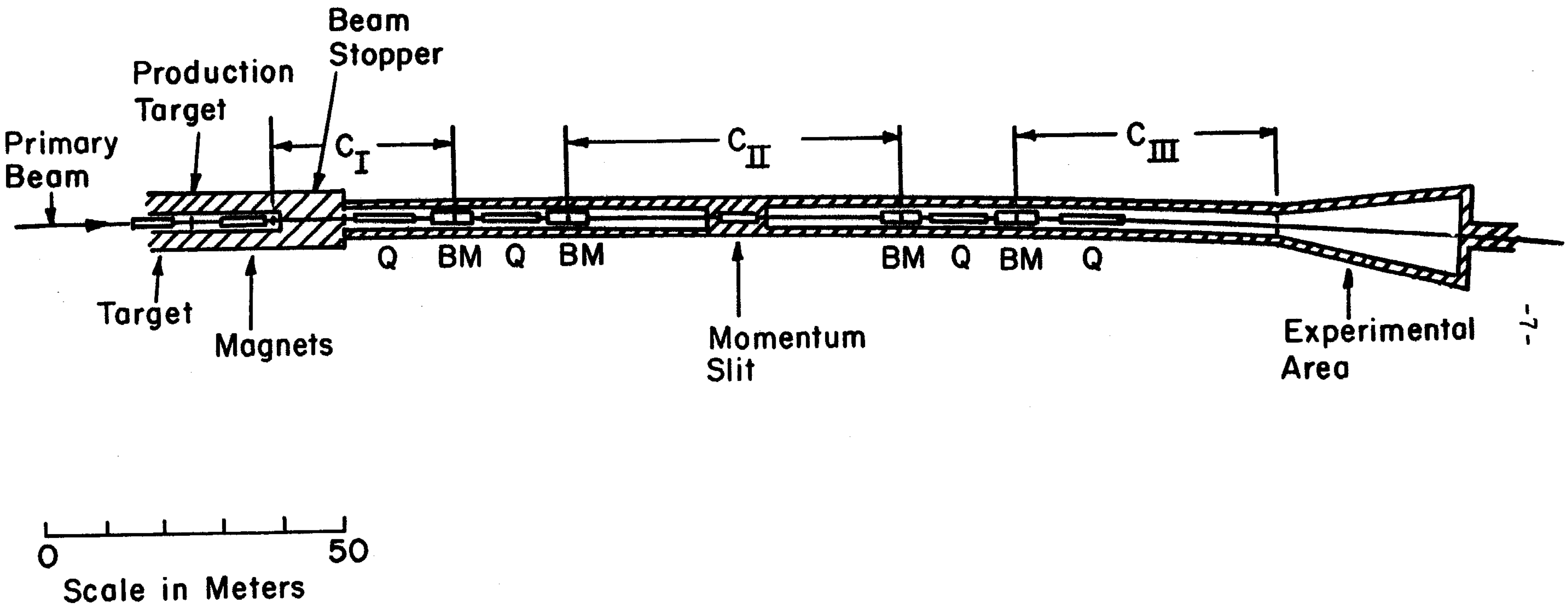
Beam
Stopper
Production
Target
Primary
Beam
C_I
C_{II}
C_{III}
Q
BM
Q
BM
BM
Q
BM
Q
Target
Magnets
Momentum
Slit
Experimental
Area
0
50
Scale in Meters

Fig. 1

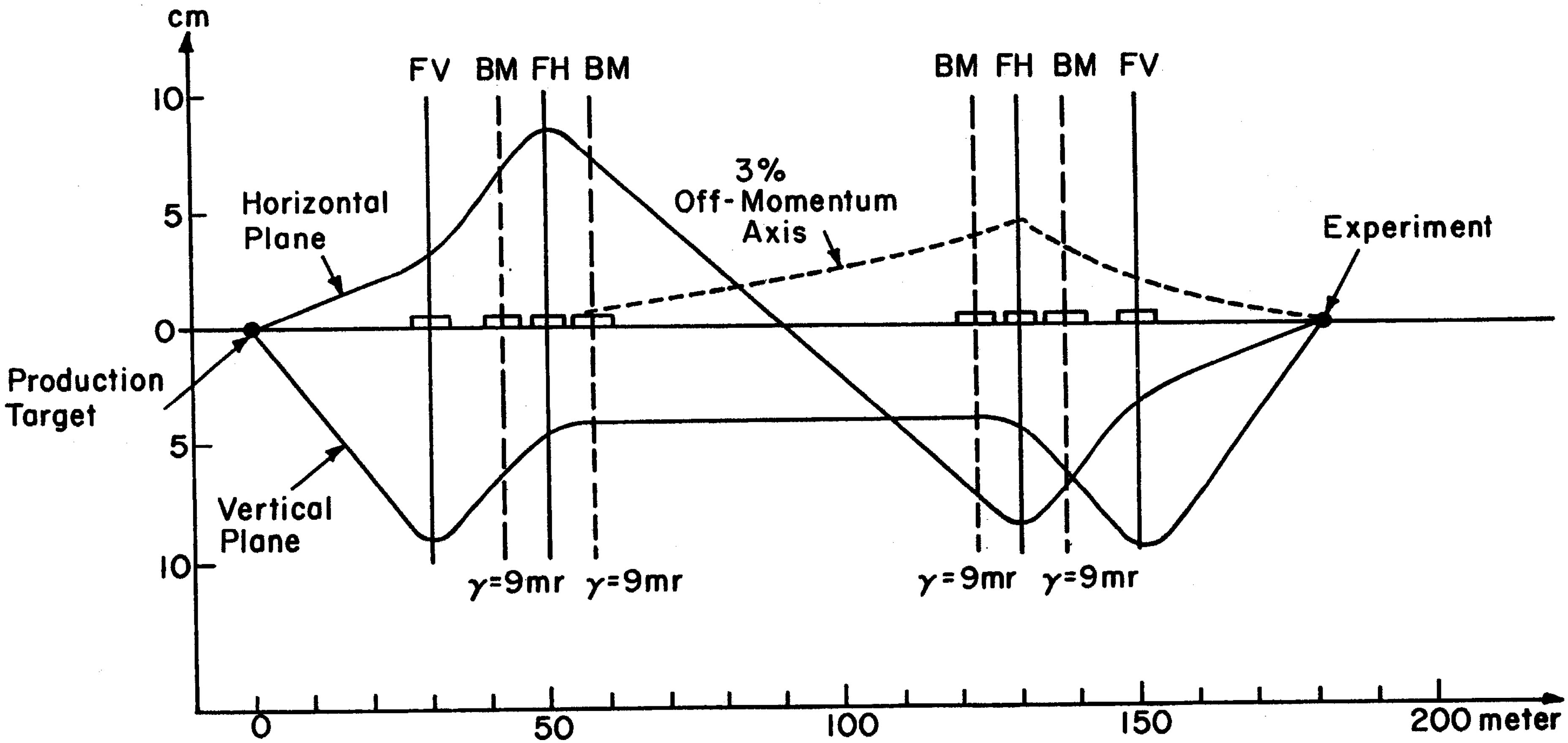

Fig. 2

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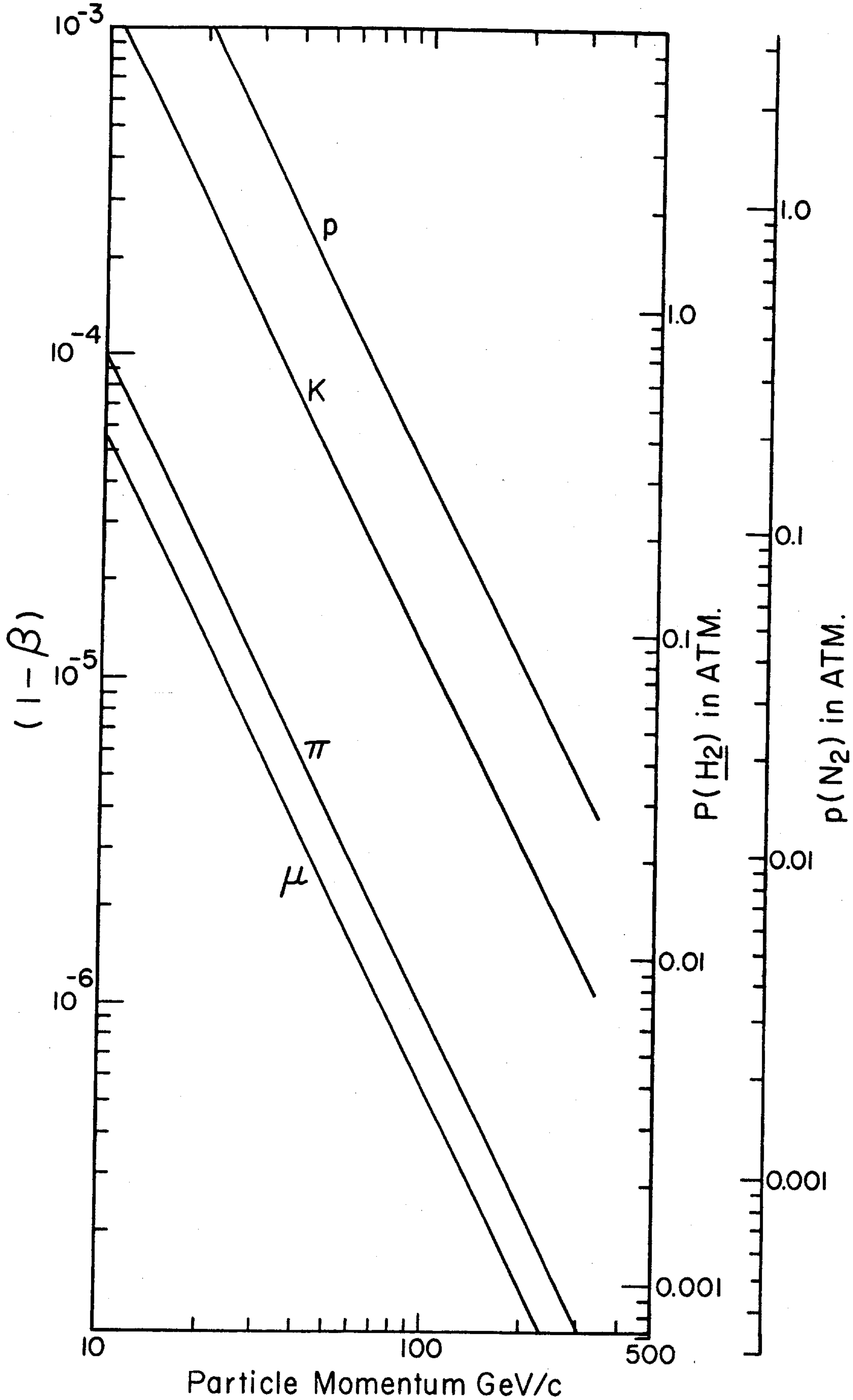
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$(1-\beta)$
p
K
π
μ
1.0
0.1
0.01
0.001
P(H_2) in ATM.
1.0
0.1
0.01
0.001
p(N_2) in ATM.
10
100
500
Particle Momentum GeV/c

Fig. 3